

We claim:

1. A method of determining eccentricity (e) of a hollow billet in the course of rolling, comprising the steps of:

(a) advancing the hollow billet in a direction along a longitudinal axis (L) of the hollow billet past at least one measuring device provided to detect the wall thickness (s) of the hollow billet at a position (z) along its length and at an angular position (ϕ) thereof or a position along its circumference;

(b) approximating a course of the eccentricity (e) of the hollow billet by the course of the wall thickness (s) as a function of the longitudinal coordinate (z) extending along the longitudinal axis (L) of the hollow billet and the angle (ϕ) about the longitudinal axis in accordance with the relationship:

$$e \propto s(\phi, z) = s_0(z) + s_1(z) \cos(\phi + \delta(z))$$

where s_0 is the mean wall thickness of the hollow billet, s_1 is the wall thickness amplitude superimposed on the mean wall thickness and δ is the angular position as a function of the longitudinal coordinate (z); and

(c) upon passage of the hollow billet past said measuring device taking a number of wall thickness measurements, feeding the measured values to a computer, and subjecting the

22 measured values in said computer based upon said approximation to
 23 a Fourier transformation to obtain a functional course of the
 24 wall thickness (s) as a function of the longitudinal coordinate
 25 (z) and the angle (ϕ) of the form:

$$26 \quad s(\phi, z) \cong s_0^* + \sum s_{i,1} \cos(\phi + 2\pi p_i z + \xi_{i,1})$$

27 where s_0^* and $s_{i,1}$ are determined Fourier coefficients for the
 28 wall thickness of the hollow billet upon summation (i) over the
 29 number (n) of Fourier series elements and whereby p_i and $\xi_{i,1}$ are
 30 the Fourier coefficients for a pitch of the course of
 31 eccentricity and for the starting angular position of the
 32 measurements upon summation (i) over the number (n) of Fourier
 33 series elements.

1 2. The method defined in claim 1 wherein the
 2 measurements are taken upstream of a rolling mill following an
 3 inclined-roll mill.

1 3. The method defined in claim 2 wherein the
 2 measurements are taken at an upstream side of a conti-rolling
 3 line.

1 4. The method defined in claim 2 wherein the
2 measurements are taken at an upstream side of a press-bench
3 rolling line.

1 5. The method defined in claim 2 wherein the hollow
2 billet is maintained against rotation about said longitudinal
3 axis (L) during taking of the measurements.

1 6. The method defined in claim 2 wherein the wall
2 thickness of the hollow billet is measured by a laser ultrasound
3 process.

1 7. The method defined in claim 2 wherein the wall
2 thickness is measured by a tool inserted into said hollow billet.

1 8. The method defined in claim 7 wherein said tool is
2 a mandrel.

1 9. An apparatus for determining eccentricity (e) of a
2 hollow billet in the course of rolling, comprising:

3 a path over which a hollow billet is advanced in a
 4 direction along a longitudinal axis (L) of the hollow billet;
 5 at least one measuring device provided along said path
 6 to detect the wall thickness (s) of the hollow billet at a
 7 position (z) along its length and at an angular position (ϕ)
 8 thereof or a position along its circumference whereby a course of
 9 the eccentricity (e) of the hollow billet can be approximated by
 10 the course of the wall thickness (s) as a function of the
 11 longitudinal coordinate (z) extending along the longitudinal axis
 12 (L) of the hollow billet and the angle (ϕ) about the longitudinal
 13 axis in accordance with the relationship:

$$14 \quad e \propto s(\phi, z) = s_0(z) + s_1(z) \cos(\phi + \delta(z))$$

15 where s_0 is the mean wall thickness of the hollow billet, s_1 is
 16 the wall thickness amplitude superimposed on the mean wall
 17 thickness and δ is the angular position as a function of the
 18 longitudinal coordinate (z); and

19 a computer connected with said at least one measuring
 20 device and receiving a number of wall thickness measurements upon
 21 passage of the hollow billet past said measuring device, said
 22 computer being programmed to subjecting the measured values based
 23 upon said approximation to a Fourier transformation to obtain a
 24 functional course of the wall thickness (s) as a function of the
 25 longitudinal coordinate (z) and the angle (ϕ) of the form:

$$26 \quad s(\phi, z) \cong s_0^* + \sum s_{i,1} \cos(\phi + 2\pi p_i z + \xi_{i,1})$$

27 where s_0^* and $s_{i,1}$ are determined Fourier coefficients for the
 28 wall thickness of the hollow billet upon summation (i) over the
 29 number (n) of Fourier series elements and whereby p_i and $\xi_{i,1}$ are
 30 the Fourier coefficients for a pitch of the course of
 31 eccentricity and for the starting angular position of the
 32 measurements upon summation (i) over the number (n) of Fourier
 33 series elements.

1 10. The apparatus defined in claim 9 wherein said at
 2 least one measuring device is located at an outlet of a rolling
 3 mill.

1 11. The apparatus defined in claim 10 wherein said
 2 rolling mill is an inclined-roll mill.

1 12. The apparatus defined in claim 9 wherein said at
 2 least one measuring device includes an ultrasonic wall thickness
 3 measurement unit having a device for launching an ultrasonic
 4 signal into a surface of said hollow billet.

1 13. The apparatus defined in claim 12 wherein said
2 ultrasonic wall thickness measurement unit includes a device for
3 measuring a time interval between two ultrasonic signals
4 including an echo signal produced by launching an ultrasonic
5 signal into said surface.

1 14. The apparatus defined in claim 13 wherein said
2 ultrasonic wall thickness measurement unit includes a laser and
3 an optical analyzer.

1 15. The apparatus defined in claim 14 wherein said
2 laser is an Nd:YAG laser.

1 16. The apparatus defined in claim 13 wherein said
2 optical analyzer is a Fabry-Pérot interferometer.

1 17. The apparatus defined in claim 9 wherein the
2 measurements are taken upstream of a rolling mill following an
3 inclined-roll mill.

1 18. The apparatus defined in claim 17 wherein the
2 measurements are taken at an upstream side of a conti-rolling
3 line.

4 19. The apparatus defined in claim 17 wherein the
5 measurements are taken at an upstream side of a press-bench
6 rolling line.